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PROTECTIVE COMPOSITION FOR THE STRANDS OF CABLES FOR PERMANENT STRUCTURES

The present invention relates to a viscoelastlic composition for the production of the strands or filaments of steel cables for permanent structures.

A field of application of the present invention is the construction of cable-stayed bridges, suspension bridges or other suspended structures and, more generally, the construction of any permanent structure in which stays, suspensions or other cables are provided to hold, suspend or consolidate a portion of the construction.

Cables used in these permanent structures are often constituted of strands (stranded assemblies of seven wires) or wires disposed in a bundle and disposed in an external tubular sleeve or envelope which is common to all the strands or to all the wires of the cable. The long lifetime required for these constructions, under conditions of complete safety, require particular care in the protection of the cables against corrosion.

On the other hand, in service, the cables are subjected to substantial vibrations, particularly under the force of wind, rain and loads applied to the structure, for example truck and/or train loads. These vibrations result in rotations or flexture of the cables near their anchors on the construction and, hence, in variations of repeated stress

(fatigue) to which the cables are sensitive. It is thus important to dampen these vibrations so as to reduce the fatigue on the cables.

Various solutions have already been used until now to protect cables against corrosion. A first known solution consists in using galvanized, waxed or greased strands and individually sheathed in a sheath with a thin wall, of polyethylene, having a thickness of about 1.5 mm. The sheathed strands are assembled in a bundle which is streamlined by an external shell or sheath common to all the strands. No filling material is injected in the sheath. This first solution is relatively costly to the extent to which the individually sheathed strands have a cost per unit weight about five times higher than of exposed strands and about twice as high as galvanized strands. Moreover, this first solution does not permit totally eliminating the risk of corrosion. Thus, because of its small thickness, the individual polyethylene sheath of each strand is relatively fragile and as a result can deteriorate in the course of transport of the strands or in the course of their handling in the factory or at the work site. If such deterioration is not corrected, the strands whose individual sheath is thus damaged can corrode more rapidly than intended.

A second solution consists in using strands or wires, if desired galvanized, which are emplaced in a common sheath whose residual internal empty space is filled by injection of a filling material serving as an anti-corrosion product. This injection has the object of ensuring long-term anti-corrosion protection for the strands. The principal injection products already known and used for this purpose, are cement slurry, petroleum wax, epoxy pitch and grease. These various known injection products have the following advantages and disadvantages:

a). Cement slurry

It has the advantage of being economical, but it has the risk of cracking, each crack thus creating a path for infiltration of moisture which can thus reach the strands and as a result give rise to their corrosion. Moreover, once set, the cement slurry is rigid, such that it fixes together all the strands. This gives rise to an increase of inertia of the cable, hence an increase of the flexural stresses. The cement slurry, once set, moreover has the drawback of not permitting individual replacement of one or several strands as needed. Finally, the cement slurry has a relatively great weight, thereby giving an increase to the dip of the cable, hence the length of the cable necessary to join two anchor points.

b). Petroleum wax

It has the advantages of being economical, flexible and permitting individual replacement of the strands of the cable. On the other hand, it has numerous drawbacks:

1) It is difficult to inject. Thus, the injection must be carried out at at least 80°C; the injection must be rapid, and hence carried out at a relatively high pressure when the cables have a great length; and the injection cannot be interrupted, otherwise the wax will solidify. The quality of the injection is hence subordinated to meticulous technique.

2) The external tubular envelope common to all the strands must have a greater thickness so as to be able to resist the temperature and pressure of injection.

3) The wax can harden in contact with the strands and prevent complete filling of the interstices between the wires of a same strand.

4) The wax does not have good mechanical characteristics. Thus, vibrating in their sheath, the strands of the cable make the wax shift and create empty spaces which thus constitute further paths for infiltration by moisture.

5) The sealing of the sheath must be guaranteed during all the life of the cable.

c). Epoxy pitch

It has the advantage of being easily injectable, provided its temperature is greater than 20°C. On the other hand, it

is toxic and not very fluid, and hence penetrates with difficulty small interstices. Moreover, after having been emplaced, it does not permit individual replacement of the strands in case of need.

d). Grease

It is easy to inject. On the other hand, it has a risk of separation of its components with time, and it does not have good mechanical characteristics, unlike petroleum wax.

On the other hand, as to damping vibrations of the cables, solutions have already been proposed and are used individually or in combination. The vibratory phenomena are generally reduced by judicious design of the surface of the sheath, which decreases the coefficient of stress and/or breaking, in case of rain, the rivulet of water oscillating along the sheath, and which is of a nature to reduce the excitative phenomena. Moreover, shock absorbers, for example of the viscoelastic type, can be placed near the anchors of the cables (lower and/or upper anchors), at a distance resulting from a compromise between effectiveness of the shock absorbers and their ease of connection to the permanent structure.

Starting from this state of the art, the present invention has for its object to provide a composition for the protection against corrosion of the strands of sheathed cables

for permanent structures, which will be easily injectable into the cable sheath, with high fluidity, even at low temperature, to be able to penetrate the smallest interstice or empty space in the sheath, whilst permitting individual replacement of one or several strands or wires of the cable whilst conferring to this latter shock absorbing properties for the vibrations to which the cable may be subjected in service.

The problem is solved by using a protective composition obtained by slow in situ polymerization, after injection at ambient temperature into a sheath surrounding the strands, of monomeric or polymeric reagents in the presence of a swelling solvent.

The starting reagents are selected such that the polymerization takes place slowly, allowing time after the preparation of the liquid, to penetrate completely the interstices between wires even in the center of the bundle of strands or wires. This slow reaction is accompanied by a slow increase in viscosity with time, due to the slow formation of a two or three-dimensional polymer which forms a viscoelastic gel under the influence of the swelling solvent.

Various types of monomers or pre-polymers can be used provided the formation of the polymer will be slow and adapted to swell in a solvent forming a gel having viscoelastic properties.

By way of example can be cited the following:

- vinyl homopolymers or copolymers, for example acrylic, obtained by thermal free radical or UV polymerization, or in the presence of a starter, of vinyl monomers or co-monomers,

- by or tri-functional compounds of two different types reacting together to give bi or tri-functional polymers, for example:

. polyurethanes obtained by reaction of polyols and polyisocyanates,

. epoxy resins obtained by crosslinking of a pre-polymeric resin, for example based on Bisphenol A or F, by a bi-functional or tri-functional amine.

Mixtures of these polymers can also be envisaged, for example epoxy/polyurethane resins.

To improve the anti-corrosion effect that the composition inherently has because of the simple fact that its presence, about the strands, in intimate contact with them and with their individual wires, it opposes the entry of water or moisture into the sheath, there can be added an anti-corrosion agent.

This agent could be selected from conventional anti-corrosion inorganic pigments, for example phosphates and particularly zinc phosphate.

There can also be used organic anti-corrosion agents such as the product sold under the name polyanilin by the company ORMECON GmbH.

When epoxy resins are used, the anti-corrosion agent is preferably constituted by an excess of amine used for cross-linking. This excess is computed such that the final pH of the composition will be ± 12.

The swelling solvent is selected from more or less volatile solvents in the form of a monomer or oligomer. There can be cited aromatic or polycyclic hydrocarbons such as diisopropylnaphthalene and the terpenes, the esters of benzoic acid, of phtalic acid or saturated or unsaturated aliphatic acids having in the aliphatic chain at least 10 carbon atoms, phenolic ethers and particularly oligomeric phenolic resins with a M_n up to 500 and preferably 350.

An example of such a solvent is the oligomeric resin NORSOLENE D 3005.

The viscoelastic and shock absorbing properties of the gel are a function of the proportion of polymer in the gel, which contains from 10 to 90% of polymer and 90 to 10% of swelling solvent, and preferably 15 to 55% of polymer.

By suitable choice of the compounds entering into the protective composition of the invention, it is also possible to provide that at the moment of injection in the cable

sheath, the injected protective composition has a density just above 1. Under these circumstances, the injected composition ejects water of condensation which may be present in the sheath.

There will now be given several examples of protective compositions suitable for the practice of the invention.

- Example 1

. Bisphenol A:	30% by weight
. Cresylglycidyl ether:	2% by weight
. Blocked isocyanate prepolymer	20% by weight
. Aliphatic amines + aliphatic amine prepolymer:	11% by weight
. Neutral and non-reactive aromatic petroleum resins and/or modified hydroxylated petroleum resins (swelling solvent):	37% by weight

- Example 2

. Bisphenol A:	17% by weight
. (2-ethylhexyl) glycidylether:	3% by weight
. Blocked isocyanate prepolymer	5% by weight
. Polyaminoimidazoline:	11% by weight
. Neutral and non-reactive aromatic petroleum resins and/or modified hydroxylated petroleum resins (swelling solvent):	64% by weight

. Example 3

. Bisphenol A:	9% by weight
. Glycidylether:	2% by weight

. Blocked isocyanate prepolymer	2% by weight
. Polyaminoimidazoline:	5% by weight
. Neutral and non-reactive aromatic petroleum resins and/or modified hydroxylated petroleum resins (swelling solvent):	82% by weight

- <u>Example 4</u>

. Butanediol + polyoxymethyleneglycol	58.1% by weight
. Prepolymer of MDI (diphenylmethane-4,4'-diisocyanate):	11.9% by weight
. Diisobutyl phtalate (swelling solvent):	30% by weight

- <u>Example 5</u>

. Urethane/acrylate polymer	35% by weight
. MMA (methyl methacrylate)	60% by weight
. Diisobutyl phtalate (swelling solvent):	10% by weight

The properties of the protective compositions indicated in the examples given above are assembled in the following table:

PROPERTIES	EXAMPLE				
	1	2	3	4	5
Viscosity of the Resin (poise)	90	26	4	4	40
Viscosity of the Hardener (poise)	50	28	20	0.5	-
Viscosity of R + D (poise)	80	28	12	1.5	40
Mode of polymerization	PA	PA	PA	PA	PA
Setting time (DPU)	40 mm	5 h	24 h	20 mn	10 mn
Elongation at rupture	35%	60%	50%	150%	250%
Rupture force (MPa)	3.0	0.3	0.05	0.5	9.8
Density	1.12	1.12	1.05	1.04	0.98
Temperature range (°C) in which tg $\delta > 0.3$ at 1 Hz	+30° to +80°	-25° to +80°	-20° to +70°	> -60°	+8° to +70°
tg δ max at 1 Hz in the temperature range	0.58	0.56	0.66	1.4	0.95

In the table, PA means "polyaddition" and PR means "radical layer polymerization". Moreover, tg δ is the ratio of the viscosity module E″ to the elastic module E′. To evaluate the viscoelastic properties of the protective compositions according to the invention, E′ and E″ are measured with the help of a rheometer with imposed deformation of the RSA II type, at different temperatures and different frequencies, and tg δ has been computed from the measured

values of E′ and E″. The above table gives the results obtained for a frequency of 1Hz.

As is well known, the shock absorbing properties of a material are greater the higher is tg δ. Tests carried out by the applicants by subjecting a sheathed multi-strand cable of 40 m to vibrations before and after injection of the protective composition of Example 3 in the sheath of the cable, have shown that this composition permits doubling the shock absorbing coefficient assignable to the cable. A similar result can be expected with protective compositions indicated in the other examples.

Thanks to its viscoelastic properties, the protective composition according to the invention gives rise to an increase of the shock absorbing coefficient of a stay cable, which increase permits:

- either omitting the local shock absorbers generally placed adjacent the anchors of the stay,

- or decreasing the size of said local shock absorbers,

- or decreasing the distance between the local shock absorber and the anchor (which has the effect of decreasing its efficiency, but permits housing it in a structure of the construction), or decreasing the cost of securing the local shock absorber to the structure of the construction.